All members are expected to attend one meeting each year for the renewal of their "spirit power." The life enjoined on the members is a life of rectitude. They are taught that membership does not exempt a man from the consequences of his sins. Lying, stealing, and the use of liquor are strictly forbidden. Various stages of initiation are described, and the appropriate songs with their music are given, each of which is accompanied by a reproduction of the mnemonic pictograph. All the songs are recorded in mnemonics on strips of birch bark, each record serving as a reminder of the essential idea of the song. The following examples illustrate these pictographs.

The Medicine song, illustrated by a figure, is: "Light—Around you—Chief—Woman." The picture was drawn by a woman, who stated that the horizontal line represents the edge of the wigwam, along which are arranged various articles of value indicated by the dots. At each end are torches, the light of which falls on the gathered wealth, causing many of the articles to glitter. These articles belong to a woman standing with upraised hands and wearing a pearl necklace with a locket. In singing this song the woman pointed to one portion of the picture after another, tapping the birch bark lightly as she sang.

The fourth song (p. 59), for initiation into the Sixth Degree of the *Midewiwin* (Grand Medicine Society), is: "Who is this—Sick unto death—Whom I restore to life?" The pictograph represents the body of the person to be initiated, on whom are seen lines representing the "strength" he is to receive through the *Mide*. "The words of the song refer to the person who is being initiated. Many sick persons are initiated in order that they may be restored to health. The *Mide* comprehends health of body, mind, and spirit in one general idea." It is somewhat unfortunate that this short memoir is simply entitled "Chippewa Music," for on reading the title a non-musical person might be led to overlook a piece of work which, as we have seen, covers a much wider ground.

As the result of two seasons' field work, Mr. Gerard Fowke has published a memoir on the mounds near the Missouri river, mainly between Gasonade River and Moniteau Creek. The mounds were erected on narrow ridges, with no regard to orientation; each contained a vault with sides sloping outwards, and composed of irregular stones. They contained one or more skeletons, either doubled up or disarticulated, the flesh having been first removed; in these cases the bones sometimes appear to have been thrown carelessly into the vault. The bones were in such a decayed and friable condition that very few could be preserved or measured. Dr. A. Hrdlička states that most of the crania are of the dolichocephalic Indian type, two or three being extreme forms in this respect, suggesting similar specimens recovered in New Jersey from the burials of the Delawares and also from the mounds of the Illinois River. A large number of the vaults are figured, as well as objects found within them. The author states that:—"As the Osage Indians never ascended the Missouri farther north than the Osage River, and as the stone vaults above that point show progressively more skill in their construction, we must attribute them either to the Kansa Indians or to some tribe whose name is now lost."

A. C. HADDON.

RADIANT MATTER.[1]

THE velocity with which helium is cast out by radio-active bodies at the moment of change varies considerably from one element to another. Thus the radiant atoms of radium C possess a far higher velocity than those of uranium or ionium. This fact is apparent in the greater distance to which the α rays of the former will penetrate in air or in any other substance. The distance traversed in air is known as the "range." The following table shows the ranges of α rays from the various known radio-active elements. Thus we see that whereas the helium from radium C is projected nearly 7 centimetres, that from uranium only reaches 2·7 centimetres. In the thorium series, one of the elements, thorium C, attains a range of 8·6 centimetres. This is the longest known.

[1] From a lecture delivered before the Royal Dublin Society on February 3, by Prof. J. Joly, F.R.S.

Range in Air.

	cm.		cm.
Radium C	7·06	Thorium C	8·6
Radium A	4·83	Thorium X	5·7
Emanation	4·23	Thorium emanation	5·5
Radium F	3·86	Thorium B	5·0
Radium	3·54	Radiothorium	3·9
Ionium	2·8	Thorium	3·5
Uranium	2·7		

	cm.
Actinium X	6·55
Actinium emanation	5·8
Actinium B	5·5
Radioactinium	4·8

By a most ingenious series of observations, Bragg has revealed some unexpected and interesting features attending the ionisation effects of the α rays upon gases through which they are projected. By measuring the amount of ionisation effected at different points along the path of the ray, Bragg and Kleeman have shown that at first, when the velocity is greatest, the ionisation effected is least, and that the amount of ionisation—that is, the number of ions created—greatly increases just before the atom comes to rest.

Let the ray be supposed to move along the line AB—this line representing the range. If at each point of its

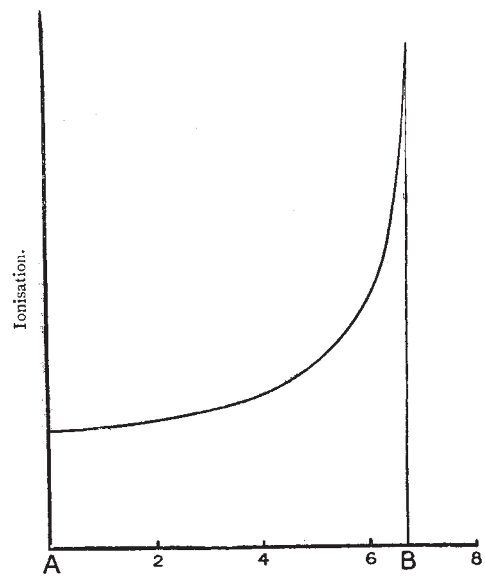

FIG. 1.—Range in cm. of air.

path we erect a perpendicular line proportional to the number of ions created by the flying helium atom, then, by joining up the ends of these lines, we obtain the curve shown. It will be noticed that a very well-defined maximum exists, after which the ionisation rapidly drops to nil. The curve reproduced is due to Geiger, who has added considerably to our knowledge of the subject.

Here is a small speck of the substance, pitchblende—the uranium ore from which radium is derived. All the elements of the uranium series are present. We are sure, then, that every α ray proper to this series, the ranges of which are given in the table, is being emitted by this particle of pitchblende. Let us form a mental picture of what is going on around it.[1]

Furthest out of all, the helium from radium C is projected. It attains a distance of 7 centimetres. The greater part by far of its ionisation is done near the end of its flight. Hence, remembering that these rays are darting radially in all directions from the piece of pitchblende, there is a shell of intense ionisation of spherical form existing around this pitchblende, and at a distance

[1] This might, possibly, be realised by condensing water vapour upon the ions according to the method described by C. T. R. Wilson (Proc. R. S., June, 1911).

of between 6 and 7 centimetres from it. This is entirely due to radium C. Within this shell we have a spherical shell due to radium A. It is the next we meet as we go inwards. It has an extreme diameter of 4·8 cm. The next shell is created by emanation. Its radius is 4·2 cm. The shell due to radium F succeeds at 3·8 cm.; then comes that made by radium, and, lastly, a very intense one due to the nearly coincident effects of three rays, two due to uranium and one to ionium. The weight of this particle of pitchblende is about one-tenth of a gram. If all its rays escaped freely at its surface, some 9600 α rays would leave it per second, and the number of ions created in the air per second would be about 960 millions. The diagram (Fig. 2) shows the successive shells, as they could be formed in air, to half scale.

We shall now pursue the study of radiant matter within the confines of another branch of science—that which deals with the nature, origin, and structure of the rocks. We gain this much by the transfer, that the invisible effects we have just been endeavouring to picture to ourselves as taking place around a radio-active body in equilibrium may be studied at our leisure, visibly inscribed in the ancient rocks. We require the microscope, however, in order to carry on our observations.

If we extract a flake of brown mica from the granite near Dublin and look at it through the microscope, we

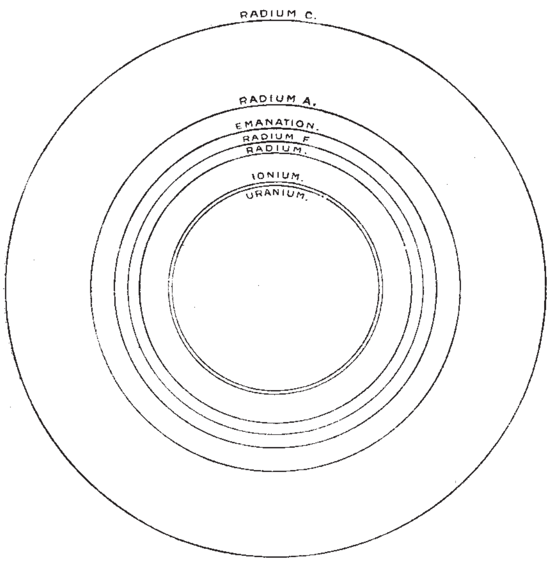

FIG. 2.

find here and there dark circular or disc-shaped marks. In the centre of each is a small crystal. This in most cases is the mineral zircon, which became enclosed in the mica at an early stage in the formation of that mineral. The dark area extends around the zircon like a darkened border, and, if the crystal is small enough, takes on the form of a perfectly true circle.

The remarkable occurrence of these dark circular spots, or "pleochroic haloes," as they are called, has been known to more than one generation of petrologists, and has always excited interest. Their origin has until lately been unexplained. Sollas, some years ago, prophetically stated his belief that they were to be ascribed to the presence of some rare earth in the zircon. When the minerals of the rocks were searched by Strutt for radio-active bodies, it was found that zircons were intensely radio-active—a concentration of uranium having in some manner taken place in these early formed bodies. The minerals apatite and allenite are also sometimes conspicuously radio-active, and around these, also, haloes often exist.

Let us then suppose that the halo is due to the radioactivity of the minute crystal around which it extends. We know that the radio-active elements in the zircon discharge helium atoms at high velocity into the surrounding mica. If these α rays have power to affect the mica by ionisation, just as they colour glass or affect a photographic plate, then there will be a certain region affected extending just so far as the rays can penetrate and no further. It will be a test of this explanation if the radius of the circular marks is found to be just the correct distance to which the rays could travel in mica.

Now Bragg and Kleeman have determined the principles upon which we may estimate from the observed ranges in air the range of α rays in any substance the chemical nature and density of which are known. Accordingly, we may calculate the ranges of several α rays in biotite. The table below gives the results.

Range in Biotite.

	mm.		mm.
Radium C	0·033	Thorium C	0·040
Radium A	0·023	Thorium X	0·026
Emanation	0·020	Thorium emanation	0·025
Radium F	0·018		
Radium	0·017	Thorium B	0·023
Ionium	0·013	Radiothorium ...	0·018
Uranium	0·013	Thorium	0·016

We see, as might have been expected, and as, indeed, was shown to you at the beginning of this lecture, that the mica is much more effective in stopping the rays than is the air. The extreme penetration of the rays from radium C is only thirty-three thousandths of a millimetre—a distance invisible to the unaided eye. This should be the limiting radius of a halo formed from the elements derived from uranium. If the thorium series was responsible, then we might expect haloes having a radius extending to the range of thorium C, that is, about forty thousandths of a millimetre. Now these are just the dimensions we find in the rocks when, by suitable appliances, we measure the sizes of haloes. Some have a radial dimension of 0·033 mm., and are then easily identified as due to the uranium series, and some scale 0·040 mm.; these are thorium haloes. Many scores of measurements confirm these results. Actinium haloes are not found; and this fact supports the inference already alluded to, that this element is derived from uranium as a very subordinate derivative, its effects being masked by the much greater vigour of the radiations from the radium series of elements. There is, then, no doubt, from the foregoing evidence alone, that haloes are the result of radiant matter.

It is of much interest to note that Rutherford has generated the equivalent of a halo in glass. In the course of experiments in which he had radium emanation contained in a capillary tube, the halo developed as a coloured border around the capillary, the radial dimensions being just such as corresponded with the penetration of α rays in glass. In the figure (Fig. 3), which I owe to the kindness of Prof. Rutherford, the central dark band is the capillary, the bordering narrow shaded area the halo.

It may also be mentioned that the experimental application of radium to biotite produces just such a darkening of the mica after some months as we see in the natural halo.

The circular or disc-like appearance of the halo is due to the fact that it is presented to us as the cross-section of a sphere. The true form is spherical. This is proved by the fact that when a crystal of mica is cut across the cleavage, the form is still circular (Fig. 5). This shows that the α rays are projected equal distances, or at least produce equal effects, along and across the cleavage—a fact not without considerable interest in itself, for it would hardly be expected on first consideration.

In the haloes which we have seen upon the screen there is no differentiation between the effects of the slower moving rays and those which move faster. The effects of the former must lie inside those due to the latter. The obliteration of the inner shells or spheres of ionisation is explained on the same principles as account for the loss of detail upon an over-exposed photographic plate. In the case of over-exposure the contrast is lost, because the effects of the lower lights have overtaken those of the higher lights, a uniform blackening ultimately resulting. If the radiant matter has been acting intensely on the mica for a very long time, the several shells of ionisation are merged in the accumulation of the feebler effects

which are always progressing at all points along the path of the ray as shown in the Bragg curve.

We should expect, however, to meet cases where, either from the smallness of the quantity of radio-active material or from the recentness of the formation of the rock, there is a proper or correct exposure, so that the successive shells of ionisation, which we may picture to ourselves as surrounding a particle of pitchblende in air, would, as developed in the mica, be made visible to the eye. In this anticipation we assume that Bragg's laws apply to the ionisation of a solid.

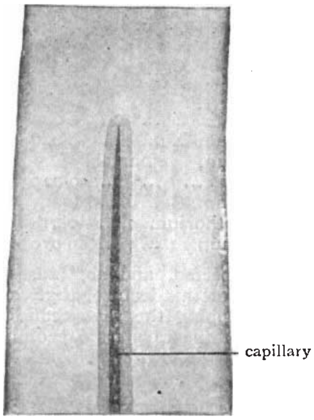

FIG. 3.

Now we do indeed find the several spheres of ionisation—or at least many of them—beautifully depicted in certain minerals, and thus we, at one and the same time, find additional, indeed overwhelming, evidence that the haloes are due to α rays, and also, what would be hard to establish experimentally, that Bragg's laws govern the effects in the solid medium.

Here is a group of well-exposed haloes in the biotite of co. Carlow. You see the outer ring due to radium C, and the gap of feebler ionisation between it and the shell due to radium A. We even find some which are actually "under-exposed." These often have got no further than the record made by the intense triple effect due to uranium and ionium. I show you this photograph again, but this time with an engraved scale of hundredths of a millimetre, which was photographed without disturbing the microscope; so that it is possible for you to verify the

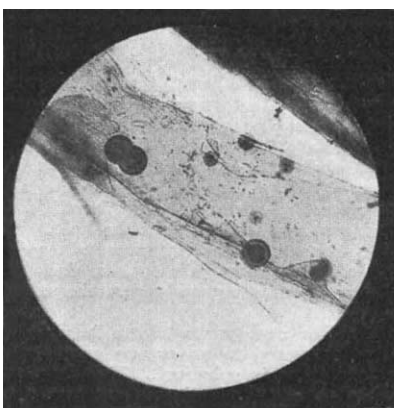

FIG. 4.—Radium haloes in cleavage plate of biotite (co. Carlow); enlarged about 76 diameters. Two overlapping haloes are present, as well as a few under-exposed haloes.

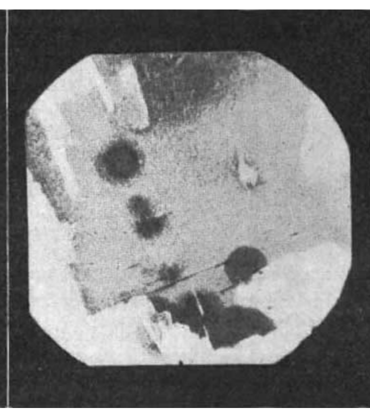

FIG. 5.—A radium halo (lower right-hand part of the field) and a thorium halo (upper left-hand part) in brown mica in a granite. The mica is cut across the cleavage. Enlargement about 114 diameters. The thorium halo shows an inner sphere due to the thorium X. The ratio of the diameters of inner and outer spheres will be found to be as 2·6 : 4·0.

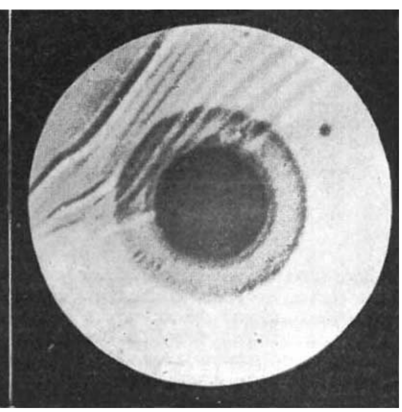

FIG 6.—A single radium halo from the Carlow biotite. It is enlarged to about 500 diameters. The inner dark disc is due to emanation. The radium A sphere succeeds and appears to be less developed than that of radium C. Viewed on cleavage.

fact that the dimensions of the fully formed haloes are all over the plate alike, and just that which the radiant matter from the uranium series of elements would account for.

It is possible to trace the development of haloes by observation of those arising from a feebler and feebler central radiation. A succession of photographs taken to the same enlargement reveals that the innermost sphere is first formed. Then this widens under the rays from radium and emanation, and the outermost sphere, for some unexplained reason, often becomes conspicuous before radium A has produced much effect. The effects of the latter rays sometimes appear as a distinct ring.

We find a striking comment on the immense age of the haloes and of the containing rocks by a study of these objects, for it is easy to show that the growing haloes we have now been looking at are the accumulated effects of ionisation acting with extreme slowness. It is calculable directly that, even if we supposed the minute nuclei of some of these haloes to consist, not of zircon, but of the most radio-active ore known, pitchblende, the rate of expulsion of the α rays has, owing to the smallness of the quantities of radio-active substances involved, been fewer than eighty in a year. But this is not all. Some of the nuclei are identified with certainty as zircons. If we ascribe to these a radio-activity even greater than Strutt found in his highest measurements, one or more years would have elapsed between one expulsion of consecutive helium atoms and another. But geological time is long; and we may still recognise in the feeblest haloes the work of many millions of atoms of radiant matter, each exerting its own small effect, but these effects carefully preserved and accumulated. In short, we recognise the halo and detect its nature and origin on the same principles as we recognise by their light-effects accumulated upon the photographic plate the presence of stars invisible to the eye.

We find, then, in the rocks a record of the laws of radiant matter in the handwriting of the radiant matter itself—a record which took many millions of years to inscribe. Haloes are not found in the younger rocks. We must clearly recognise the halo as the result of the integration of effects of unimaginable feebleness; and as we see them in the Archæan granites, they probably date their beginnings from times long antecedent to the appearance of life upon the globe, not fewer than 100 million years ago.

They assure us, therefore, of the remote antiquity of the atomic instability which calls radiant matter into existence. But even more they tell us of the enduring stability of the ordinary elements. If the common and abundant elements which occur in and around the mica emitted radiant matter, even at the slowest rates, the clear transparency of the mica must long ago have vanished, and the whole become obscured under the effects accumulated during the ages which have elapsed since the formation of the rocks.

We seem entitled to conclude that the atomic stability and instability which we observe to-day have prevailed during geological time.